

Chapter 5

RAIL TRANSIT

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This chapter will provide an overview of rail modes as they are applied to urban public transportation. Included is fully grade separated rail rapid transit with various degrees of automation. Second is light rail transit and its highest refinement, light rail rapid transit, which have received renewed interest in the United States. Third and last is regional rail or commuter service, best exemplified in the Chicago, Philadelphia, Boston, and New York areas of the United States and in Toronto in Canada.

The general physical and operational characteristics of these modes will be briefly explained and a few examples of each cited and described. The intent is for students, planners, engineers, and other interested individuals to obtain an overall picture of what each submode can do in the urban and suburban environment.

First, let us look at the components of rail transit. Whether conventional rail rapid transit, light rail transit, or a regional rail system, they have certain common features. First, there is the track and, second, the flanged wheel. The steel rail and flanged steel wheel were devised in the early nineteenth century for intercity railroad use. They were well developed by the latter part of that century, and during its last three decades, steam-powered urban railways were built in a few cities. The elevated railways in New York and Chicago were built during this period. They used 25-ton steam locomotives that could pull six light coaches at about 25 ml/h. This speed merited the term rapid transit when compared to the horse-drawn traffic below.

Beginning in the 1830s and 1840s, horse-drawn street railway systems were built in many cities. By the late nineteenth century, thousands of horse-drawn cars were in use. Practical application of electricity as motive power to replace the costly horses developed quickly after pioneer installations proved workable. By 1900, many street and elevated railways had been converted to electric power, and by 1910, this conversion was essentially complete. New routes followed rapidly until a peak was

reached in the early 1920s. The street railway then moved into the suburbs—and far beyond—in the form of the interurban electric railway. The latter is best exemplified by the once-great Pacific Electric Railway of the Los Angeles region, then the world's largest interurban railway under one management with over 1000 mi of routes. During this period, the flanged steel wheel on steel rails was refined to a highly reliable system with many special devices to meet specific needs.

From 1930 to the mid-1950s, a rapid decline in urban surface street railways took place, owing to the greatly increased use of private automobiles in urban areas, with motor buses often taking over the ridership of the replaced street railways. Nevertheless, rail rapid transit held up relatively well. Streetcar lines having private rights-of-way also held up well because they had a competitive advantage over private automobiles or street-bound buses. The resurgence of interest in transit has focused attention on the modes and submodes that did hold up well during the decline of transit, that is, the grade separated or semiseparated rail modes.

THE GUIDEWAY

The rail guideway is the only form of guideway in general use throughout the world. The railway track is formed of T-rails that weigh, for modern applications, 85 to 132 lb/yd (42 to 65 kg/m). Track gauge is generally 4 ft 8.5 in (1.44 m), a dimension inherited from England, which, in turn, inherited it from the Romans. Light rail and rapid transit, however, have various gauges from 1 m (3.3 ft) in Europe to 5 ft 4.5 in (1.63 m), Baltimore's former streetcar gauge; San Francisco Bay Area Rapid Transit (BART) uses 5 ft 6 in for stability, but Los Angeles Railways streetcar lines used 3 ft 6 in for economy of construction. Pittsburgh and Philadelphia light rail lines use 5 ft 2.5 in, as does New Orleans' one remaining street railway line. Anything reasonable will work, but, generally, standard gauge (4 ft 8.5 in) has been used because of the easy availability of railroad hardware.

For many years, railroads and most existing urban railways have used wood ties, with rails spiked to the ties. Construction in the 1970s began to favor concrete ties with various kinds of pads with spring clips to hold the rail. Concrete promised to last longer, and because of their weight, such ties hold the rails down more firmly. Concrete slabs under track have been used in Europe and in some subway installations in the United States.

Use of the flanged steel wheel on the rail has provided a positive guidance system for over 150 years. Switches and crossings are fully designed and have proved reliable. Railroad track may be ordered from catalogs and is suitable for most rapid transit and many light rail applications. Older street and interurban railway geometric designs may still be quite suitable for proposed new light rail installations. Some innovation in trackwork has appeared in Europe and has been duplicated in the United States in a few places where it was desired to emulate the smoothness of European trackage.

The metallurgy of the rail and wheel has been thoroughly studied, particularly for railroad use, and both items are fully engineered and available. Their service life is known, so costs and operational ability can be forecast with confidence. Railway track can be, and has been, installed (1) on private right-of-way on the surface, as ordinary railroad track, (2) on elevated or aerial structure; (3) in subways; (4) in median strips on boulevards or freeways; and (5) in paved streets as streetcar track or light rail track.

PUEBLO TEST TRACK

In 1971, the U.S. Department of Transportation dedicated a test facility near Pueblo, Colorado, for railroad and rail transit research and development. Several types of track were installed, arranged as several test loops, and a stub-end impact track was provided. Included is a small loop of 4.8-mi (7.7-km) circumference with curves of up to S° and grades up to 2%. It is labeled the FAST track, for Facility for Accelerated Service Testing. A "typical" freight train operates 16 h/day to produce 1 million ton-miles per day on this track to life-test both track and rolling stock. Another objective is to learn more about train/track dynamics. Roughly, 1-year testing at FAST is equal to 10 years of real-world service.

The Pueblo facility also includes a 9.1-mi (14.6-km) oval to test urban and suburban rapid transit and light rail vehicles. It is electrified with a conventional 600-V third rail, and part of it is equipped with catenary at the same voltage to test light rail vehicles. A specially built substation can provide several voltages and can simulate certain electrical faults.

The outcome of the railroad and light rail transit testing at Pueblo should be improved life and reliability for a mode that already typically has long service life and high reliability for its components.

RUBBER-TIRED SYSTEMS

Automated rubber-tired guideway systems have been developed since the mid-1950s. A moderate number are in use in major activity centers such as airports, resort complexes, and academic campuses. One, Miami's Metromover (Florida), performs a downtown people-mover function. Chapter 24, on new technology, delves deeper into automated people movers. In this chapter, only the rubber-tired rapid transit vehicles developed in Paris and used, for example, in Montreal, Mexico City, and Sapporo (Japan) will be discussed. These systems use a conventional railway track for switching and return current, plus vertical third and fourth rails for positive current and guidance. The rubber-tired main carrying and traction wheels run on a concrete (or other material) runway immediately outboard of the standard-gauge railway track. Proponents of this mode point out that the rubber tires allow use of grades of up to 6%, whereas conventional heavy rapid transit is limited to 4%. While generally true, grades of up to 5% are found on heavy rail elsewhere, an example being the transition from subway to the Benjamin Franklin Bridge on PATCO's Lindenwold Hi-Speed Line. Light rail has examples of even greater grades, with several 7% grades on the Sacramento light rail line.

The rubber-tired system was dramatically more quiet than older conventional heavy rail systems in use when the Paris and Montreal systems were inaugurated. Later improvements in conventional rail systems, however, have reduced the difference to the point that there is little noise difference to the passenger.

It has been found that the rubber-tired systems use more power than do steel wheel systems because of the flexing of the tires. One result is that the subway tunnels used by rubber-tired trains are noticeably warmer. The cars are narrower and shorter than those used on contemporary heavy rail lines; the narrow cars allow narrower tunnels which are somewhat less expensive to build. One reason for the smaller cars is that the weight-carrying capacity of rubber tires is less than that for steel wheels. On the other hand, more cars and more trains are needed to provide the same capacity. A classic trade-off analysis will reveal which alternative is preferable for a given sitespecific application. The rubber-tired rail-guided submode remains relatively uncommon.

MONORAIL

Every generation or so, various forms of monorail are rediscovered and promoted, and each time their inherent drawbacks are learned anew by those who have neglected to study the history of technology as applied to urban transportation. It has been said that monorail is the mode of the future, and, except for limited installations, it always has been and probably always will be!

The Wuppertal Schwebebahn or Suspended Railway in Germany has often been cited by monorail enthusiasts. It has been in successful operation since the very early twentieth century; From time to time, it has been provided with new rolling stock. But it has not been extended. Increased transit provided in the area has been by surface light rail or by suburban railroad. If the suspended monorail had all the merit many of its proponents claim, it would seem that its originators in Germany would have expanded the mode. See Table 5-1 on page 95 for comparative information on this mode.

SOURCE OF ENERGY

Urban railways have almost always been electrically operated, usually employing 600 volts direct current (V dc) or some variation of it, such as 700 or 750 V dc. In a very few cases, self-propelled equipment using internal combustion engines has been used (for example, the diesel-electric streetcars of Sapporo). Such arrangements are possible but are seldom used in actual practice. An unusual, interesting, and successful example of nonelectrified rail transit is found in the northern suburbs of Hamburg, Germany. There, three different light rail lines feed the Hamburg transit system, one

using large articulated light rail vehicles with diesel-electric drive while two use fourwheel rail cars with diesel-mechanical drive.

The use of a moderately low voltage direct current has distinct advantages. Only one current collector is needed on the vehicle and the rails act as the ground return. The simplicity of this single collector should not be ignored. Some of the more novel modes that have been promoted use three-phase alternating current, typically 480 V. These need at least three collectors, and in one case five (two more for ground and signaling), all of which adds to complexity and, in turn, unreliability. A considerable amount of equipment is already developed and available for the usual 600- to 750-V dc system.

Regional railroad service most commonly uses diesel-electric locomotives to haul trains, but in New York City, Philadelphia, and Chicago electric power is used. Some rail diesel cars are self-propelled.

Regional railroad service can be defined as having routes approximately 15 to 50 mi in length, with frequent stops, typically 1 to 3 mi apart. It is distinctly different from intercity high-speed railroad passenger service, such as is provided by the Metroliners in the Northeast Corridor of the United States, the TGV (Train of Great Speed) of France, or the Shinkansen lines in Japan. The latter routes are several hundred miles long with stops 50 to 100 mi apart.

RAIL RAPID TRANSIT

OLDER SYSTEMS

In the United States, the form of urban rail transit that presently carries the most people per year is rail rapid transit. This mode is characterized by full grade separation, electric propulsion, multiple-unit trains, and speeds of 45 to 80 ml/h (72 to 130 km/h) maximum, and 20 to 50 ml/h (32 to 80 km/h) overall schedule. The very extensive New York City Transit Authority (NYCTA) subway system has nearly 7000 cars and represents, by itself, the majority of rail rapid transit in the United States. Its use of four-track subway routes with local and express trains is unique (except for Philadelphia's Broad Street Subway), as is its common use of 10-car trains. Crowding in NYCTA trains is legendary, and official standards call for 255 passengers per 60-ft (18-m) car, at 2.3 ft² (0.2 m²) of floor area per passenger. Thus, a 10-car train will handle 2550 persons, and on some routes such trains operate every 2 min in the peak, carrying passengers at the rate of 76,500/h past a given point. This rate is seldom achieved for more than 15 to 30 min, however.

Such volumes are not found elsewhere in the United States, and the student of urban transportation should recognize that there are unique New York problems. Other cities, such as Boston, Philadelphia, and Chicago, have rail transit systems dating from the same period as New York's, about 1905-1940, with some more recent

extensions. Routes in these cities typically handle from 50,000 to 300,000 passengers/day, with perhaps 15 to 20% of the day's travel during each peak hour.

In older intraurban systems, stations are typically a quarter- to a half-mile apart. Chicago's average spacing is 3700 ft (1100 m). In more modern systems, center-city stations are similarly spaced, but in the suburbs, spacings of 1 to 2 mi are more common. In past years, planning was based on walk-on patrons or transfer riders from surface streetcar lines. Emphasis in the suburbs now is on highway access by park-and-ride and kiss-and-ride or feeder bus service. Boston had a highly developed streetcar feeder system with streetcars operating down into subway stations or up onto elevated stations. Several such stations have been converted for trolleybus and motor bus access to provide what is often considered the most convenient transferring on any U.S. system.

Fare collection on these older systems is mostly by cashiers in booths, assisted by coin- or token-operated turnstiles. In Chicago, during the off-peak on lightly used routes, conductors hand-collect fares on two-car trains in a manner not seen elsewhere for many decades. Conductors collect fares on board trains at certain unattended stations in Philadelphia during "owl" (midnight to 5 a.m.) hours.

Operating costs of traditional, labor-intensive rail rapid transit systems tend to be high because of two-person (operator and conductor) train crews and the attended stations necessary for fare collection. On the other hand, with very high volumes (found in only a few places), cost per passenger is sometimes quite low.

MODERN SYSTEMS

Modern rail rapid transit is an evolutionary development of traditional rapid transit. It is fully grade separated and uses railway track and direct-current electrification at moderate voltages, 650 to 1000 (up from the older 600 V dc). It stresses highperformance trains with running speeds of 70 to 80 ml/h (112 to 130 km/h), averaging 35 to 50 ml/h (56 to 80 km/h), and employs some forms of automation. The first generation of these systems opened in 1969-1972 and is exemplified by the Bay Area Rapid Transit (BART) in the San Francisco area of California and the Port Authority Transit Corporation (PATCO) connecting Philadelphia to southern New Jersey. Both systems were designed specifically to compete with the private automobile. They feature fast, frequent service and convenient highway access, with large park-and-ride lots at outlying stations.

Trains are one-person-operated to reduce operating expenses, this being made feasible by various forms of automatic train operation (ATO). Automatic fare collection in the stations keeps all money under lock and key and minimizes station staff.

Modern rapid transit is expensive to build, but the modern operating properties have proved that the American motorist can be attracted to transit if the service is fast, frequent, and reliable. (For example, over 90% of PATCO's daily riders start their trip by getting into a private automobile and driving, or being driven, to a station, then getting out of the automobile and into a train for the remaining journey to center city.)

Major corridors carrying large volumes of passengers between a relatively small number of points are the best places for modern rail rapid transit. Good highway access is essential, as is good downtown distribution from relatively closely spaced stations to provide convenient pedestrian egress. Environmental impacts are usually favorable as compared to the automobile. The ride can be pleasant as well as fast. It can be a very positive asset to a metropolitan region.

BART

The BART system as completed in 1970-1972 has 71 mi (115 km) of route of which 19 mi (31 km) is in tunnel and 23 mi (37 km) is elevated on dual-track concrete structure. There are four lines with 34 stations. BART's designers chose a broader-than-standard track gauge at 5 ft 6 in (1.7 m) to achieve better lateral stability in high winds. They selected 1000 V dc for electrical engineering reasons: the higher voltage delivers more power with less loss and requires fewer substations. It is a nonstandard voltage, however, and requires custom-built equipment on board the trains. BART also chose a newly developed form of signaling and train control, the reliability of which is still not completely demonstrated. To attain the very high frequency (short headways) of a train every 90 s, BART's designers opted for a central computer so that trains from the three-branch system could funnel into the Transbay Tube from Oakland to San Francisco with a minimum of delay. It should be noted that BART's signaling and control system has not attained 90-s headways even after substantial investment in modifications.

Stations feature automatic fare collection with change-making ticket vendors that accept coins and bills. A heavy paper ticket with a magnetic data stripe is vended for whatever sum (up to \$40) is inserted by the passenger. The passenger then inserts the ticket into a gate's ticket slot and the stored-value ticket is read, encoded for the station of entry, and returned to the passenger passing through the gate. At the destination, the passenger inserts the ticket into the exit side of a gate and the gate reads the ticket, deducts the value of the trip from the value on the ticket, and returns the ticket to the passenger. An "add fare" machine allows a ticket with insufficient value to be upgraded for exit at that station. Stations have attendants at all times to provide information to passengers and to deal with minor problems with the AFC system.

BART has 440 cars from its original 450-car 1970-1972 fleet, composed of A cab cars that must be at the end of a train and B blind motorized cars used between A cars. In 1987-1990, 150 C cars were delivered that have one cab and end door that can be coupled within trains. All trains are operated by one person.



Figure 5-1 BART—the first post-World War II U.S. rail system. Lake Merritt Station, Oakland. (courtesy of Harre W. Demoro Collection)



Figure 5-2 BART—Rohr rapid transit cars. (courtesy of Rohr Industries, Inc.)

A program to increase capacity is underway to permit operation of 57 trains rather than 43 as in the past. An extension of the tail tracks (track extending beyond a terminal station that is used for turning back or storing trains) at Daly City terminal allows more capacity to reverse and to store trains. Major extensions to Warm Springs, Dublin, San Bruno, and Pittsburg are under study.

Although BART has had highly publicized problems in its train control equipment and in the cars themselves, it nonetheless has proved to be automobile-competitive and has captured many new riders for transit in its region. Its trains average about 50 ml/h (80 km/h); they have operated at 77 to 80 ml/h (124 to 129 km/h) running speed, passing vehicular traffic on nearby freeway lanes; and its filled parking lots, crowded trains, and plans for extensive extensions attest to its popularity. Its technical problems have been ameliorated if not completely solved.

BART especially proved its value to the San Francisco Bay region after the October 17, 1989, earthquake when it was the only intact crossing between San Francisco and Oakland. It carried nearly double its usual volume of passengers and retained many of them after the San Francisco-Oakland Bay Bridge was restored to service.

PATCO

In contrast to the vast BART undertaking of providing a regional system in essentially one overall effort, the Delaware River Port Authority (DRPA) developed a single line to connect the suburban borough of Lindenwold, New Jersey, with centercity Philadelphia, a distance of 14.2 mi (22.9 km). The DRPA had little choice; that was all it could afford using its own resources in 1962. A three-branch system had been proposed and is still an objective, but so far only the central line has been built. The designers chose evolutionary development of conventional technology, partly because the new line was to use the existing 3.8-mi (6.1-km) Philadelphia-Camden Hi-Speed Line over the Benjamin Franklin Bridge, a route opened in 1936 using a heavyweight, deluxe subway-type car. Standard-gauge track with a conventional third rail was already in place. There was little reason to change the conventional technology since it could easily provide the performance desired: a 75-ml/h (121-km/h) running speed, 3.0mi/h/s (1.3-m/s²) acceleration, with an average speed of about 34 ml/h (54 km/h), the latter influenced by sharp curvature and steep grades on the older part of the line.

The new construction, from Camden to Lindenwold, used the right-of-way of the Pennsylvania-Reading Seashore Lines, a jointly owned subsidiary of the Pennsylvania Railroad and the Reading Company. This line had been very much underutilized and was finally abandoned and the land sold to the Delaware River Port Authority. Much of the original railroad track was at grade, but DRPA converted it to a fully grade separated facility. The inner part is on embankment or concrete aerial structure, a short segment through Haddonfield is in a walled cut, and the outer 6 mi is at grade, passing over a few streets, with one road passing over the line. A shop and yard at the outer terminus complete the physical plant.

Stations feature fully automatic fare collection, with no employees permanently

assigned to any given station. Roving supervisors check each station frequently, and part-time employees manually sell tickets during the morning peak hours at suburban stations, but, generally, stations are unattended. They are under closed-circuit TV surveillance from Center Tower, PATCO's control center in Camden, New Jersey. The passenger service representatives observe the TV screens and can communicate with passengers by using a public address system or through a call-for-aid telephone in each station. Unattended stations allow PATCO to have one of the highest ratios of passengers to employees of any transit facility in the United States, about 130 passengers per day per employee. During most of its first years (1969 - 1975) of operation, PATCO earned its operating expenses from the farebox. More recently (1984- 1989), it recovered about 76% of its expenses from fares, the highest recovery rate of any United States heavy rail system.

PATCO's cars have four series-wound dc motors and use a cam controller with resistors. A General Electric ATO (automatic train operation) system working in conjunction with a 100-Hz (hertz) Westinghouse Air Brake Company (WABCO) cab signal system controls the trains. The 100-Hz system has been in use since 1925, having been pioneered by the Pennsylvania Railroad. While PATCO's version had improvements, the principles were already well proved.

The original 75 cars were built by the Budd Company in 1968 and are almost completely stainless steel. They have proved to be extremely strong and have stood up remarkably well. As a result, when more cars were required, 46 nearly identical cars were acquired in 1980 from Vickers Canada, Inc., under license from the Budd Company. Improvements to enhance reliability were incorporated into these cars which operate in trains at the same performance level of the still used 1968 Budd cars.

Since it opened, PATCO has operated 24 h/day, 7 days/week, continuously. Trains run every 10 to 12 min in midday, every 2 to 8 min in the peak hours, every 12 min in late evening, and every 40 min all night. On Sundays, a 20-min headway is provided. One of PATCO's purposes is to provide an around-the-clock service that people can count on. There is no "last train" to catch. Patrons can always get back to their automobiles parked in one of PATCO's lots. Meanwhile, PATCO's own police will look in on the cars from time to time to minimize theft or vandalism.

PATCO takes pride in the fact that it has operated 99% of its trains on time (within 4 min of timetable) on a yearly basis. From 1969 to 1980, it ran 70 of its 75 cars in each peak hour, 5 days a week. Only five cars were not needed for scheduled service, and of these, three or four were in scheduled maintenance; thus, only one or two cars were available as spares most days. PATCO cars are designed for quick changeout of defective components; that was the key to running 70 of the available 75 cars twice a day. And that is why the DRPA and its subsidiary, PATCO, plan on continuing with evolutionary improvements of the conventional. It has worked well in practice.

Expansion to three routes was planned, to be funded by state and federal governmental agencies; preliminary feasibility and engineering were completed in 1975, but funding has not yet been found.

Other U.S. Systems

Modern rapid transit systems have been built in Washington, D.C., Miami, Baltimore, and Atlanta, and a new line is under construction in Los Angeles. These systems share major concepts with BART or PATCO or both: high performance with automation to varying degrees.

Washington Metro (WMATA) began operation of a short segment of its projected 103-mi (165-km) regional system in 1976. Ridership on this initial portion exceeded preliminary estimates. Metro's consultants selected standard-gauge, conventional third rail, and a 750-V dc power supply, along with a conventional resistance controller used in conjunction with automatic train operation. Later cars have dc chopper control that permits regenerative braking, smoother acceleration and deceleration, less energy losses when accelerating, and lowered periodic and corrective maintenance. The system has been relatively free of significant technical failures such as those that affected BART.

Metro uses an automatic fare collection (AFC) system of the stored-value type that permits fares to be related to distance and that, in addition, provides data necessary to determine subsidies from the several political entities that constitute WMATA. Metro features bus-to-train transfers, park-and-ride lots, and fast, frequent service.

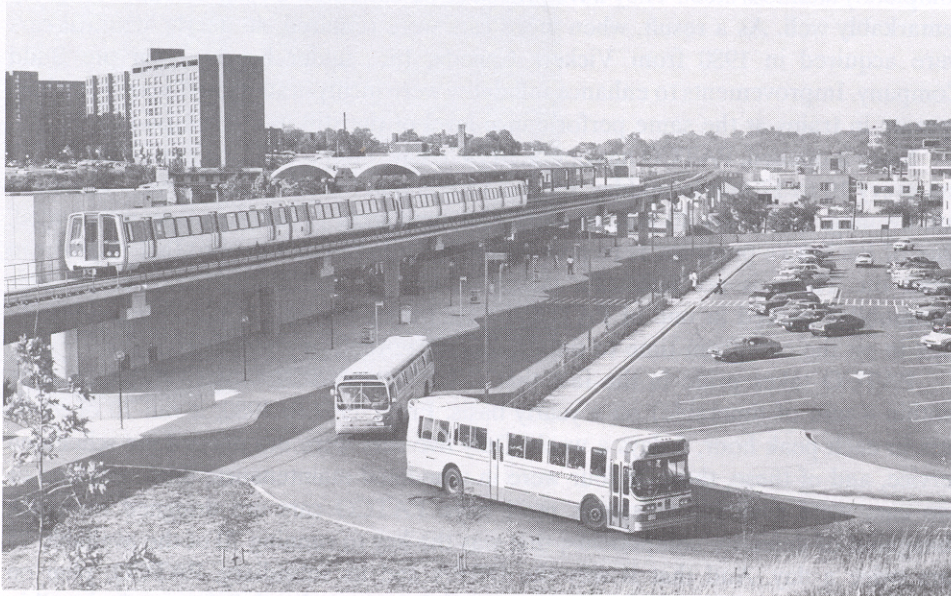


Figure 5-3 Washington, D.C., Metro—Rhode Island Avenue Station. Note convenient feeder-bus access. (photo by Phil Portlock, courtesy of Washington Metropolitan Area Transit Authority)



Figure 5-4 Washington, D.C. Metro—Metro Center Station. (photo by Paul Myatt, courtesy of Washington Metropolitan Area Transit Authority)

Metro has experienced very high construction costs, so consideration was given to truncating the planned system, but Congressional support has been strong and construction has continued, with added segments of the system opened throughout the 1980s. Completion of the full 103-mi system is scheduled for the mid-1990s. While it has been expensive to build, it has yielded significant benefits, the primary one being that it has made it easy for persons to travel by transit throughout the District of Columbia and its suburbs in Virginia and Maryland.

The *Metropolitan Atlanta Rapid Transit Authority* (MARTA) is another relatively new system. Its construction began in 1975 and the first line opened in 1979. It is a cross-shaped system with a north-south line and an east-west line. The south terminal serves Hartsfield International Airport, one of the busiest airports in the United States. As of 1989, MARTA had 32 mi (52 km) of route, 29 stations, and 200 cars. The latter are 75 ft (22 m) long and slightly over 10 ft (3 m) wide and operate on standard-gauge track using 750-V dc third rail at up to 70 mi/h (112 km/h). Stations are generally unattended and employ automatic fare collection.

Long-term plans call for a 53-mi (85-km) rapid transit system with 39 stations. MARTA is a completely coordinated regional transit system (unlike BART and PATCO which are rail only) that includes a 750-bus fleet, which provides feeder and connecting services.

Baltimore Metro is operated by the Maryland Mass Transit Administration, a state agency. It has a single line, 13.9 mi (22.4 km) long, of which almost a third is tunnel.

The outer segment to Owings Mills, which opened in 1987, is in the median of an interstate highway. A 2-mi subway extension to Johns Hopkins Hospital from the present center-city terminus at Charles Center is under construction.

A 100-car fleet of stainless steel cars was delivered in 1983-1986. The cars are 75 ft long and 10 ft wide and operate at up to 70 mi/h on standard-gauge track with a 750-V third rail.

Baltimore Metro is part of an integrated regional transit system that has an 800-bus fleet. A light rail line is under construction with 35 light rail vehicles on order.

Dade County Metrorail, serving Miami, Florida, is a contemporary of Baltimore Metro and shares the same car design. The single 21.4-mi (34.5-km) line runs generally north-south and is entirely elevated except for a few short segments passing under elevated highways. The system has 136 cars and 20 stations with both AFC and attendants. Most outlying stations have park-and-ride lots. An additional station in the central business district (CBD) has been proposed at the river bend, where Metrorail crosses the Miami River on a high bridge.

Metrorail is part of an integrated regional system that includes Metrobus (544 vehicles) and Metromover, a downtown people mover using Westinghouse Electric rubber-tired technology. Metromover is fully automated with unattended stations and serves to distribute Metrorail passengers locally throughout the CBD. Extensions to Metromover are in progress.

The systems built in Atlanta, Baltimore, and Miami are generally similar in that the cars are about the same size, have about the same performance, operate on standard-gauge track, employ 750 V dc with automatic train operation, and use automatic fare collection of various technologies.

Los Angeles Metro Rail will follow the same basic technology for its Wilshire Boulevard subway, of which 4.4 mi (7 km) is under construction, with much more planned. Cars will be similar to those of Baltimore and Miami, but will be constructed in Italy rather than in the United States. -

LIGHT RAIL TRANSIT

A speaker at the first light rail conference in Philadelphia in 1975 said that "Light rail is a state of mind" that does not have a precise technical definition. By 1989, the state of mind had become concrete enough for the TRB Subcommittee on Light Rail Transit to define a light rail transit (LRT) system as "a metropolitan electric railway system characterized by its ability to operate single cars or short trains along exclusive rights-of-way at ground level, on aerial structures, in subways, or, occasionally, in streets, and to board and discharge passengers at track or car floor level.")

LRT is an evolutionary development of the street railway toward modern rapid transit. It usually uses overhead electric power distribution and employs cars much like streetcars, but possessing higher performance. Its track is usually segregated from

traffic, but not necessarily grade separated throughout. Often median strips of boulevards or freeways are used. If vehicular traffic is light, track can be in the street. In congested city centers, subway or aerial structure often provides full grade separation. In some European and North American cities, the track area in center city is reserved solely for light rail vehicles or as a paved mall for pedestrians and light rail vehicles.

The light rail vehicle (LRV) often operates as its own feeder. Access is very convenient, so that even though the lack of grade separation enforces lower speeds than for modern rail rapid transit, overall door-to-door speeds may be quite attractive. In 1960, Frankfurt, Germany, studied three alternative systems for providing improved transportation. The three alternatives were supported monorail (Alweg), light rail transit, and conventional rapid transit, mostly in subway. Table 5-1 gives information on the salient features of the three systems studied. It is interesting to note that in this study it was determined that the total peak passenger travel time is less for the light rail transit alternative. This is a result of the self-feeding feature.

Light rail, having evolved from the streetcar, can accommodate very sharp curvature, steep grades, and a variety of station configurations, from the simplest to the most grandiose. Grades of up to 9% and horizontal curvature of 42 ft (13 m) can be taken by the articulated Boeing-Vertol light rail vehicle (LRV) built for Muni and Boston in the 1970s. Older streetcar equipment, such as PCC streetcars, can take a 36-ft (11-m) radius, at low speed, of course. Such curves and grades are found in paved street trackage.



Figure 5-5 Boeing-Vertol light rail vehicles. A two-car train at Longwood Station on Boston's Riverside line on a test run in 1976. These cars entered revenue service during January 1977. (courtesy of Boeing-Vertol)

TABLE 5-1
Comparison of Monorailway, Light Rail Transit, and Conventional
Rapid Transit System Designed for Frankfurt

Item	Monorailway		Light Rail Transit	Conventional Rapid Transit
Route length of railway (mi)				
In tunnels	2.83 ^b	13.15	23.76	
On elevated way	36.30 ^c	4.42	15.42	
On separate roadbed	—	46.48	—	
Total	39.18	64.03	39.18	
Year of completion	1968	1974	1981	
Number of rail stations	82	192	91	
Average distance between stations (ft)	2,387	1,686	2,099	
Total number of stations and stops	307	349	316	
Average speed for rail system (mi/h)	17.76	16.02	17.53	
Numer of pear-hour passengers	95,600	95,600	95,600	
Percentage of peak-hour passengers				
Not transferring	21.0	36.7	24.6	
Making 1 transfer	44.3	47.8	45.3	
Making 2 transfers	29.3	14.1	24.3	
Making 3 transfers	5.4	1.4	5.6	
Total peak transfer move- ments	113,500	76,519	106,812	
Total peak passenger travel time (h)	52,200	49,300	50,300	
Adjusted anual cost of system for first 10 years (no interest)	\$22,900,000	\$16,100,000	\$22,700,000	
Anual cost as percentage of present street rialway costs	95	47	93	

aMetric conversion: 1 mi = 1.6 km; 1 ft = 0.305 m.
bWith alternative plan: 4.3 mi (6.9 km).
cWith alternative plan: 34.7 mi (55.8 km).

Source: Adapted from Gordon J. Thompson, "Light Rail Transit Social Costs and Benefits," in *Light Rail Transit*, Special Report 161 (Washington, D.C.: Transportation Research Board, 1975), p. 149. From translation by Charles J. Lietwiler of K. Leibbrand, "Stadtbehn Frankfurt-am-Main—Planerische Gesamtübersicht," City of Frankfurt-am-Main, Germany, 1960.

Light rail trackage, electrification, and structures are generally much lighter and less costly than for rail rapid transit. Since the LRVs are not notably lighter or cheaper than rapid transit cars, the big savings in LRT are in the civil engineering features. Because it requires less investment, light rail is often justified in corridors having less traffic than is required to justify investment in full-scale rapid transit. Furthermore, light rail can be upgraded one segment at a time to provide performance nearly equal to grade-separated rapid transit. The investment need not be made all at once.

PCC CARS

Until the 1970s nearly all existing light rail lines in the United States and Canada were operated with PCC streetcars. The initials PCC stand for the Presidents' Conference Committee of electric railway company presidents that was formed in the late 1920s and operated in the early 1930s to supervise the creation of a radically new street railway vehicle to stem the decline in ridership then afflicting the transit industry. A sum of about \$700,000 (eventually to reach about \$1,000,000) was raised from member street railway companies and from suppliers, nearly all of whom were in difficult financial straits. (Consider that inflation by a factor of 15 to 20 has taken place since that time.) C. F. Hirschfeld of the Detroit Edison Company was chosen to head the project team.

Hirschfeld's team attacked the problem using one of the first applications of systems analysis. First, the physics of motion were studied, including what changes in the rate of acceleration and deceleration a standing passenger could tolerate. Next, sources of noise were studied. Then the duties of the motorman were analyzed. Other factors were studied intensively. A truly integrated design resulted. The car body, trucks, and propulsion were designed as a "system," not merely a collection of different manufacturers' parts, as had been the industry practice.

It was recognized that one car size could not meet the needs of every operator; therefore, a limited number of variations was made available. While the standard car was single ended, a few were built for double-end operation, and while most PCC cars were single-unit streetcars, some were built for multiple-unit (MU) operation, with couplers. Three lengths, 43, 46, and 50 ft, and three widths, 8 ft 4 in, 8 ft 8 in, and 9 ft, were offered. The 43-ft car, 8 ft 4 in wide, was unique to Capital Transit Company of Washington, D.C. All the 50-ft cars were 9 ft wide, while the popular 46-ft car was built in all three widths.

The two major electrical suppliers, General Electric and Westinghouse Electric, designed control and propulsion equipment to meet Hirschfeld's specifications. While the designs of the controllers were different, they were compatible in performance and could run together in multiple-unit trains. Over 6000 such cars were built for use in the United States and Canada between 1936 and the mid-1950s. Some of these PCC cars are still in operation. In 1990, Toronto opened its Harbourfront line, which uses rebuilt PCC cars along with Canadian LRVs. Several builders in Europe were licensed to build them, and construction has continued in Belgium and Czechoslovakia.



Figure 5-6 PCC testing. Engineers are shown making tests to obtain data to improve riding comfort for the PCC car. (courtesy of American Public Transit Association)

LRT VERSATILITY

Muni

San Francisco Municipal Railway (Muni) has implemented a true light rail system, the Muni Metro, with subway under Market Street in center city, using car-floor-height platforms, and at-grade track in the outlying residential areas. Although the track is at grade in these outlying areas, some is on private right-of-way, some is in a highway median strip, while some is in a paved street but separated from vehicular lanes by roughened paving. Automotive vehicles can drive on this rough paving in emergency, but normally the area is reserved for the light rail vehicles. In still other places, the light rail vehicles run as ordinary streetcars. The cars are trainable and have convertible steps to allow loading from both floor-height platforms and street level. There are five lines in the system, which merge into a single line that runs under Market Street. Up to four-car trains are possible, and the highest planned volume is 9000 passengers/h. Speeds of up to 55 mi/h (88 km/h) are attainable in the subway, but only 25 to 40 mi/h (40 to 64 km/h) are allowed on the surface portion. The train

operator needs a positive signal indicated by the "green light" (using the 100-Hz cab signal system the rails carrying the signal) to be able to achieve that higher speed in the subway. In the absence of that signal, the vehicle cannot go over a set speed, say 41) or 35 m/h. Muni's full use of the light rail concept merits careful study and observation by rail system planners.

M & O Subway

Light rail is versatile and flexible and can be designed to meet a very wide demand. At one end of the spectrum is San Francisco Muni's major semimetro system, at the other end is the M & O Subway. Tandy Center (Radio Shack) in Fort Worth, Texas, has its own light rail line named after Marvin and Obie Leonard, the founders and previous owners. In 1963, Obie Leonard bought five ax-Washington, D.C., PCC streetcars, laid about 1.5 mi (2.4 km) of track, reworked the cars to make them appear new, added air conditioning, built a huge parking lot along the flood plain of a river, dug a very short subway to the basement of the store, and happily hauled thousands of people into the store every day. The ride is free.

The track is about on a par with a railroad industrial siding. Speeds are low, 15 to 25 ml/h (24 to 40 km/h). The power supply is said to be ex-United States Navy submarine generators, war surplus. The trolley poles are short mine type, so they will fit in the subway. The whole system is a triumph of ingenuity, but the subway is especially so. The street was opened (various buildings of the Tandy complex front on both sides) and war-surplus Quonset huts were installed end to end. Then the street was backfilled—an instant subway with arched roof. It leaks a bit, but it works.

No Urban Mass Transportation Administration (UMTA) funds were involved, nor were local government funds. No large-scale professional consulting engineer reports were made. The work was largely done in-house by company maintenance forces who converted the old District of Columbia trolleys from single-end streetcars to double-end, air-conditioned, high-platform light rail vehicles. It is a marvel of practical engineering. The Tandy Subway was modernized in the 1980s by building a three-track terminal at Tandy Center and totally rebuilding the cars with the boxy bodies of contemporary LRVs. The parking-lot-shuttle type of operation could be quite useful in a variety of situations in smaller communities where a planner might not normally consider rail transit of any kind.

Pittsburgh

Pittsburgh's LRT line to the South Hills combines several features to yield a unique line. Because it is a rebuilt street railway line, it retained the 5-ft 2.5-in gauge of the Pittsburgh Railways Company. New sections of private right-of-way, including a downtown subway, feature high-platform stations with attendants and conventional fare collection. Segments of paved-street track use low-platform loading through a single-stream door adjacent to the train operator.

The right-of-way includes a new subway, a recycled massive railroad bridge across

the Monongahela River, a reused streetcar tunnel through Mt. Washington, rebuilt street railway on private right-of-way, some rebuilt street track, a new tunnel in Mt. Lebanon (with no station), and some new right-of-way. It is an excellent illustration of the versatility of light rail transit.

Skokie Swift

Another rail variation is the Skokie Swift line of the Chicago Transit Authority (CTA), a 5-mi (8-km) shuttle line using one-car one-person-crew trains. It feeds the northern terminal of the Chicago mainline subway/elevated line from the suburban village of Skokie. The line has only two stations, a park-and-ride station in Skokie and the Howard Street terminus of the El. It is popular, economical to operate, and a worthwhile addition to Chicago's rapid transit system. While it uses high-platform rapid-transit-type cars, the CTA considers it light rail because of the one-car trains and at-grade construction of much of the line—an abandoned interurban electric railway taken over by the CTA for this purpose.

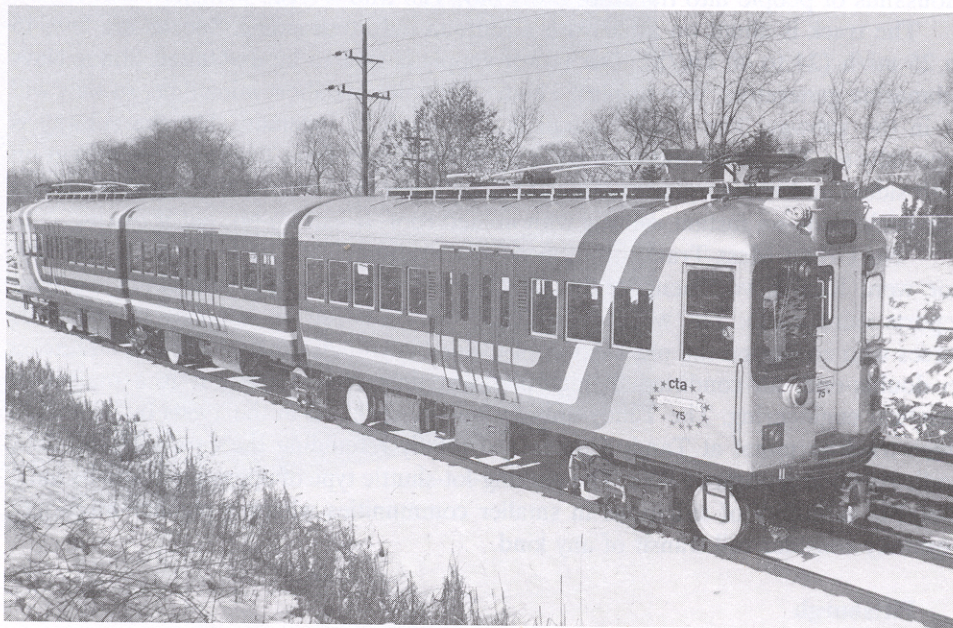


Figure 5-7 Skokie Swift. Chicago's articulated "Paul Revere" in Bicentennial livery is used as a one-man operated unit on the suburban line. Skokie trains are equipped with both third rail and catenary current collection. (courtesy of Chicago Transit Authority)

Newark

The Newark (New Jersey) City Subway, which opened in 1935, should not be overlooked. It is at the light end of the LRT spectrum. The shortest of publicly owned light rail lines at 4.2 mi (6.7 km), it provides very frequent service with 22 PCC streetcars (single unit, single end, fare collection on board, 600-V current collected by trolley pole). There are 11 stations of which 4 are in the 1.2-mi (1.9-km) subway portion. The line was built in the bed of the abandoned Morris Canal in order to remove some streetcar lines from the congested streets of New Jersey's largest city. This location provided full grade separation except for one grade crossing. Newark's other streetcar lines were converted to motor bus in the 1940 1950s, leaving Route 7, City Subway, as the sole surviving light rail line in New Jersey. The second-hand PCC cars were acquired after a proposal to convert the line to a dual-mode trolleybus line was rejected.

New Jersey Transit Corporation (NJT) rehabilitated Route 7 in the late 1980s. The PCC cars were overhauled in-house and are meticulously maintained. Procurement of new LRVs was considered, but it was concluded that the rehabilitated PCCs could do the job.

Route 7, City Subway, is merely one route in the vast bus system operated by NJT Bus Operations, Inc. At its Franklin Avenue outer terminal, connection is made with several bus lines. Along its route, a number of bus lines are intersected. At Penn Station, Newark City Subway reaches NJT's major hub, where connections are made with the commuter rail lines of NJT Rail Operations, Inc., with numerous bus lines, and with Amtrak's Northeast Corridor. The heaviest and lightest of rail modes meet in this location.

These illustrations are a sampling of the versatility of LRT systems. Older services in such diverse cities as Boston, Philadelphia, New Orleans, and Toronto are also good examples of the ability of LRT to be molded to the needs of the cities it serves.

MODERN U.S. AND CANADIAN SYSTEMS

Edmonton

Edmonton, Alberta, Canada, brought the new generation of light rail to North America on April 22, 1978, when its 4.5-mi (7.2-km) route opened. It featured all highplatform stations, U-2 cars built by Siemens-Duewag in Germany, a downtown subway, with the line then rising to grade, to share a railroad right-of-way. Because of grade crossings, speed was a modest 30 mi/h (48 km/h). Work on a southern extension to the University of Alberta is under construction (1989-1992) and will include a bridge over the North Saskatchewan River. Further extensions are planned.

Two- and three-car trains are operated in the peak hours. There were 37 cars in the fleet as of 1989. Self-service proof-of-payment fare collection is employed. The line is an integral part of the Edmonton Transit System and is the furthest north of any North American rail transit line.

Calgary

Calgary, Alberta, some 185 mi (296 km) south of Edmonton, has built an all atgrade LRT system. The initial southern line opened in 1981, a northeast line in 1985, and a northwest line in 1987. It is high-platform, proof-of-payment fare collection, and operates through a downtown pedestrian and transit mall (with buses). As of 1990, it had 17 rte.-mi (27 rte.-km) of double track, with more under construction, and had a fleet of 83 U-2 cars. There are two routes, both sharing the center-city mall.

The more extensive at-grade Calgary C-Train system contrasts with the short subway and surface line in Edmonton and illustrates how rapidly a system can be expanded at grade.

San Diego

The initiator of the modern generation of light rail line in the United States is operated by San Diego Trolley, Inc. It was built by the Metropolitan Transit Development Board, opening for service on *July 26*, 1981, between the Santa Fe Railroad station in downtown San Diego, and extending south 15.9 mi (25.4 km) to San Ysidro, California, on the Mexican border adjacent to Tijuana. Fourteen SiemensDuewag low-platform U-2 articulated LRVs provided service over what had been the San Diego & Arizona Eastern Railroad. Initially, the line was single track, with sidings or short sections of double track spaced to allow a 15-min headway.

Nicknamed the "Tijuana Trolley," the line was instantly popular, resulting in pressure to add more cars and double track. These improvements were carried out over several years. Trains grew from two to three and eventually four cars. The fourth car is uncoupled to operate separately in the street in central San Diego because a four-car train blocks cross streets. An eastern extension to Euclid Avenue opened in 1986; it was continued to La Mesa and El Cajon in 1989 to total 32 mi (51 km) of route. A short 2- ml route along the waterfront in San Diego creates a triangular loop between the end of street trackage and the Santa Fe station. Additional extensions are under study.

The MTDB continues freight train operation using a private contractor, the San Diego & Imperial Valley Railroad. Most freight train activity is at night.

Portland

Portland, Oregon, opened MAX (Metropolitan Area Express) between center-city Portland and Gresham City on September 8, 1986. The line operates in paved streets in center city. From there it is located in a freeway median, in the median of Banfield Boulevard, and thence in a former electric railway right-of-way to Gresham, 15.1 mi (24.2 km) to the east. The last 2.5 mi is single track. The 26 articulated low-platform LRVs can attain 55 mi/h (88 km/h). Maximum train length is two cars in deference to cross streets in downtown Portland. MAX is unusual in U.S. practice in that a magnetic inductive train stop system is used to enforce red block signals.

Historic-appearing new single-unit streetcars have been acquired to provide a local service within the downtown area. Portland's MAX has enjoyed unusually heavy weekend traffic, with Saturdays often being busier than weekdays as a result of a festival market and other CBD attractions. The Portland line has been very well accepted by the area residents, is well used, and can be an example to transit planners elsewhere. A western extension is under study.

Sacramento

Sacramento, California, opened its LRT line, RT Metro, in 1987, using 26 Siemens- Duewag U-2 articulated low-platform LRVs. The U-shaped route consists of the 9-mi (14-km) North Line and the 9.3-mi (14.9-km) East or Folsom Line. About 60% of the line is single track, with sidings spaced to allow a 15-min headway. Trains of up to four LRVs are operated.

The North Line uses a segment of what was intended to be an Interstate-80 bypass. Ballasted track rests on top of never used concrete pavement near the Watt/I80 station and on a graded but never-used right-of-way east of the car shop near the Marconi-Arcade station. The line was constructed using interstate transfer funds from the abandoned I-80 project. Its designers used some of the most innovative approaches applied in the United States to LRT and achieved one of the lowest costs per routemile of any new system at about \$10 million/mi. In the downtown area, track is in a pedestrian mall, in the rest of center city it is in paved streets. Extensions are planned.

San Jose

The 20-mi (32-km) Guadalupe light rail project being built by the Santa Clara County Transportation Agency opened its first section of line on December 11, 1987. It was followed by the section to downtown San Jose, California, which opened June 17, 1988, to total 9 rte.-mi (14 rte.-km). The next unit opened on August 17, 1990 (11 weeks ahead of schedule). This section extends the service about 2 mi south of center city to a station that will be shared with the extended Caltrain commute rail service in late 1991 when the last section of the initial system will also open. The system is all double tracked and has 33 stations.

Fifty LRVs were obtained from the Urban Transportation Development Corporation of Canada. They have air suspension and are air conditioned. Their top speed is about 65 ml/h, but they will operate at 55 ml/h. Additional local service within the CBD of San Jose is provided by a small fleet of restored historic trolleys, some of which actually operated in the region.

Service extensions for areas north of San Jose (Milpitas, Santa Clara, Mountain View, and Sunnyvale) are being studied.

Los Angeles - Long Beach

The 21.5-mi (34.4-km) Los Angeles-Long Beach light rail line, built by the Los Angeles County Transportation Commission, opened on July 14, 1990. It restores service along 16 mi (26 km) of a route that had been operated by the Pacific Electric Railway Company (PE) from 1902 to 1961. There are 33 grade crossings (all with warning devices and gates), but five major grade separations eliminated a number of at-grade PE crossings of streets and railroads. The 54 articulated LRVs are high platform, have a top speed of 55 mi/h, and were built in Japan. The line uses cab signals, which, with the high-platform stations, places this line at the heavier end of the light rail spectrum.

The LRT line is part of the regional transit system operated by Southern California Rapid Transit District that will later include Los Angeles Metro Rail and the 16.5-mi (26.4-km) Century Freeway automated light rail line. The Long Beach line will share the 7th & Flower Street subway station of Metrorail in downtown Los Angeles when it is completed in 1991.

All the West Coast LRT lines except San Francisco Muni Metro use the proof-of-payment fare collection system with off-train vending of tickets in conjunction with periodic inspection on board. This method is reported to work well.

St. Louis

Bi-State Metro Link, 18 mi (29 km) long, will connect East St. Louis, Illinois, with St. Louis, Missouri, its western suburbs, and Lambert International Airport by 1993. It will use the historic (1854) Eads Bridge, a 4500-ft railroad tunnel, and underutilized railroad rights-of-way. It will employ high platforms and a few grade crossings (all with warning devices). Thirty-one LRVs were ordered from Siemens in 1990. They are very similar to those used in Pittsburgh.

Baltimore

In 1989, Baltimore ordered 35 very large LRVs, 95 ft (28.5 m) long and 9.5 ft (2.9 m) wide, for its 28-mi (45-km) north-south LRT line. It will operate at grade in a pedestrian mall in downtown Baltimore, and hence can be considered classic LRT.

Buffalo

Buffalo's LRT line opened October 10, 1984, featuring a double-tracked line 1.2 mi (1.9 km) long in a paved pedestrian mall on Main Street. The remainder of the line, in subway, opened in September 1986 to provide a 6.2-mi (9.9-km) route. The subway portion employs high-platform stations; the street trackage employs low-level loading with retractable steps on board the cars. Conceptually, it is somewhat like SF Muni, only reversed—on street downtown and in subway elsewhere. This is a legacy of its initial planning as a true rapid transit subway system throughout; however, its potential

ridership did not meet federal requirements for full rapid transit. Consequently, the plan was altered to become generally light rail rapid transit with some surface operation LRT downtown.

The 27 cars are single-unit (nonarticulated), double-truck, double-end cars built in Japan, equipped with a U.S. propulsion system, and assembled in the United States.

Several extensions have been proposed and provision was made in the subway structure for a junction as well as an extension.

Niagara Frontier Transportation Authority, operator of the line, had a difficult financial situation that culminated in a system shutdown (including the extensive bus system) in early 1990. After a few days, new funding was agreed upon by city and county authorities, and the system resumed operation.

LIGHT RAIL RAPID TRANSIT

Light rail rapid transit (LRRT) is a composite of rail rapid transit and light rail. The one characteristic that differentiates LRRT from LRT is an exclusive, gradeseparated right- of-way for the entire system, which qualifies the system as true rapid transit. LRRT systems may have low- or high-level platforms or both. They may be run with either visual or signal control. Many LRT systems have sections that qualify as LRRT and, in a few cases such as Buffalo, the whole system is referred to, although inaccurately, as light rail rapid transit.

CLEVELAND

The composite of light rail and rapid transit is exemplified by the Greater Cleveland Regional Transit Authority (GCRTA) Red Line route from Windermere in East Cleveland to Cleveland Hopkins Airport on the far-southwest side of that industrial city. The GCRTA 19-mi (30-km) rapid is fully grade separated, uses overhead electrification and high platforms, and runs one-car one-person-operated trains in off-peak hours, with fare collection on board. During peak hours, two- or three-car trains are operated with two- person crews (operator and conductor) and station collection of fares. Speeds are moderate, 55 ml/h (88 km/h), and headways relatively frequent. The GCRTA rapid hauls about 20,000 persons per day.

About 2.6 mi (4.2 km) of its track is shared with the Shaker Heights (Blue and Green) line, which operates articulated Breda light rail vehicles utilizing low-platform loading. The Shaker Heights line is also owned and operated by the GCRTA, but it was originally constructed in 1919 as a transportation link between downtown Cleveland and a new land development.

Cleveland was a pioneer in large-scale park-and-ride lots, along with extensive and well-coordinated feeder bus lines. It has shown that rapid transit can be successfully provided in areas of moderate population density and high auto ownership. Most of

the areas served by the GCRTA rapid and the Shaker Heights light rail are single homes, with a modest sprinkling of apartments.

An interesting facet of the Cleveland rail system is the use of the word rapid as a noun. This word, usually an adjective, is used to describe the system as "The Rapid" or a car or train as "a rapid." This use evolved among the local population.

INTERMEDIATE CAPACITY TRANSIT SYSTEMS

A variation of light rapid transit is the Intermediate Capacity Transit System (ICTS) developed by the Urban Transit Development Corporation of Ontario, Canada. It is based on a standard-gauge railway track as a guideway, with 600-V dc, third-rail power distribution. There its similarity to conventional technology ends.

The ICTS features a small bus-size car powered by a linear induction motor (LIM) controlled by an on-board V dc-ac inverter. A variable block system is used to enforce train separation, with block length proportional to speed. The lower the speed is, the shorter the block, allowing closer train spacing and more throughput. Full automation is designed into the system; no on-board train operator is required. Speeds of up to 50 ml/h (80 km/h) are attained along with acceleration of 3.0 ml/h/s (1.3 m/s²), as fast a rate as is customary for either light or heavy rail.

Radial axle trucks are used along with flanged wheels that are smaller in diameter than those customarily used on rapid transit or light rail cars. These wheels are not used for propulsion or braking, those functions are provided by the LIM. A friction parking brake is provided. The radial truck is intended to reduce flange wear.

The ICTS inherently requires full grade separation. Most existing mileage is on elevated structure, with some surface and a very small amount of tunnel mileage. The small profile provided by the small car body on small wheels allows a small tunnel.

By 1989, ICTSs had been installed in three locations in North America. The first was in Vancouver, British Columbia, where it is called SkyTrain and first operated in 1986 for Expo '86. It performs a line-haul function and is over 13 mi (21 km) long, plus a recently opened 2-mi (3-km) extension with more extensions planned. It is the backbone of Vancouver's transit system and provides a high level of exceptionally frequent service with two-, four-, and six-car trains.

In Toronto, Canada, an ICTS line 4-mi (6.4-km) long provides a feeder service to the east terminal of the Bloor-Danforth subway line. Toronto initially opted to employ train operators on its trains. The change was made to automatic operation during 1989- 1990, although an on-board attendant was retained.

In Detroit, the ICTS is used as a downtown people mover under an UMTA-funded demonstration project. One- and two-car trains are operated on a single-track continuous loop 2.9 mi (4.6 km) long.

While all three installations encountered some "teething" problems, such as are usually encountered in new technology, all provide a high level of service that is attractive to users. The ICTS has demonstrated that full automatic operation is workable in the North American environment.

COMMUTER RAILROAD

Commuter railroad service has existed on a major scale continuously for many years in New York, Philadelphia, Boston, Chicago, and San Francisco. Typically, railroad commuter services have very heavy peak-hour service with little, or even no, off-peak service. Regular interval service of a train every 30 to 60 min in off-peak periods is generally considered good, with peak-hour trains every 4 to 30 min. It is not uncommon for a certain corridor in major cities to have only three inbound trains in the morning and three outbound at night. A number of medium-size cities had or have one train each way daily on certain routes. This all means that most, indeed all, railroad commuter services are heavy losers financially if evaluated of and by themselves. They often handle "the peak of the peak," however, and so reduce the need for investment in plant and equipment to handle a peak load by some other mode, whether highway or transit.

If freight train conflicts can be reduced or eliminated, commuter service can begin to approach rail rapid transit in frequency and convenience. As long as trains are operated by railroad employees represented by railroad unions, traditional labor practices ensure high operating expenses and a high probability of significant deficits. Nonetheless, at times it is still an attractive alternative financially and is nearly always popular with passengers. Some public transit agencies operate commuter trains directly with their own employees at transit pay rates and work rules with resulting lower costs. Because underutilized railroad track exists in many places, it is often possible to run a few peak-hour trains by providing only added locomotives, cars, and labor. The expensive fixed plant, a right-of-way through an urban area, is already there. Therefore, to a public transit agency, contracting for railroad commuter services may at times be an attractive alternative to massive investment in other modes.

EASTERN UNITED STATES

In the New York and Philadelphia metropolitan areas, most commuter trains consist of electrically powered multiple-unit cars. Many of these are relatively new and have performance approaching that of modern rail rapid transit. Single-level commuter rail cars are typically 85 ft (26 m) long, 10 ft (3 m) wide, and 14 ft (4 m) high and seat from 90 (in 2-2 seating) to 130 (in 3-2 seating). Some use 600 to 650-V dc third rail; others use catenary overhead at 11,000 V ac, 25 Hz; and one, the New Haven, uses both. New York area stations have floor-level platforms since the New York systems use high-platform cars. Philadelphia favors ground-level loading at most stations.

For the newer equipment, acceleration is in the range of 1.5 to 2.2 ml/h/s (0.67 to 0.98 m/s²). Top speed is generally 85 ml/h (137 km/h), but certain cars were designed to reach 100 ml/h (160 km/h). But only the Jersey Arrow cars running the 58 mi (93 km) between Trenton, New Jersey, and New York City (Penn Station) regularly reach that speed. For longer suburban journeys of about 50 mi, such high speeds could reduce trip times substantially, but only if the number of stops is strictly limited.

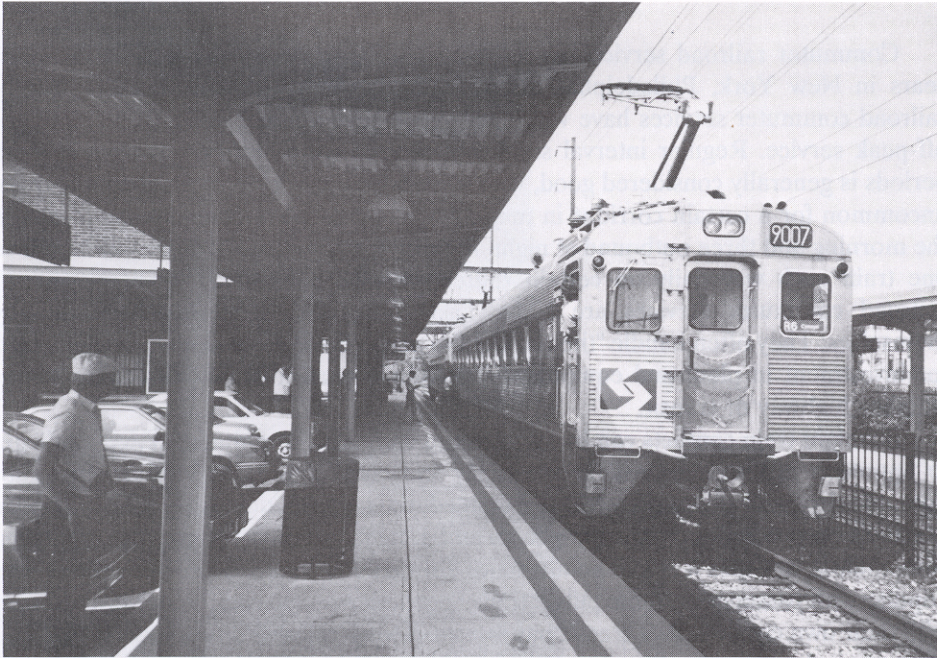


Figure 5-8 SEPTA—Silverliner II at DeKalb Street, Norristown, Pennsylvania. These suburban commuter cars are used in the Philadelphia area. (courtesy of J. William Vigrass)

In the Boston area, an extensive and moderately intensive service is operated by Amtrak for the Massachusetts Bay Transportation Authority (MBTA). Service is provided by diesel-electric-powered, push-pull equipment using ground-level low platforms. Two distinctly separate services are operated: from North Station over Boston & Maine trackage and from South Station over former New Haven Railroad line trackage as well as ConRail (formerly Boston & Albany).

CHICAGO AREA

In Chicago, most suburban railroad service is with bilevel coaches seating 140 to 160, pulled or pushed by medium-horsepower diesel-electric locomotives. These trains load from ground-level platforms. A driving cab is located in the rearmost car of the train to remotely control the locomotive in the push mode. This type of operation minimizes switching and fosters fast turnaround. The bilevel cars are some 16 ft (5 m) high, a height that cannot be accommodated in the below-ground terminals in eastern cities.

All Chicago suburban rail services are operated by railroad owners under contract to METRA (Metropolitan Rail), an agency of the Chicago Regional Transportation

Authority Operators include the Burlington Northern, Chicago & North Western, and the former Rock Island line, which has had a succession of owners.

Two Chicago railroad lines are electrified. The Illinois Central Gulf(ICG) uses a 1500-V dc catenary system. The line runs south from the Chicago Loop, along Lake Michigan's shoreline. There are two branches. A fleet of bilevel high-platform cars was acquired in the 1970s, partly with public funds.

The Chicago South Shore & South Bend Railroad has a single route from South Bend through Michigan City and Gary, Indiana, to downtown Chicago, using ICG rails within Chicago. The South Shore line is largely in Indiana yet received no financial aid from Indiana sources until 1978. Public funds were made available in the late 1970s through the Northern Indiana Commuter Transportation District (NICTD). The NICTD's funds are severely limited but were adequate to obtain 44 new electric multiple-unit cars built in 1981-1982 by Sumitomo (of Japan) with General Electric (U.S.) propulsion equipment similar to that provided for the ICG cars. The South Shore cars are single deck and thus somewhat lighter than ICG's bilevels. The South Shore cars attain speeds of 70 to 75 ml/h (112 to 120 km/h). Low-level loading is used at South Shore's own stations.

SAN FRANCISCO BAY AREA

In the West, only one area, San Francisco, presently has extensive commuter railroad service. It is provided by Caltrain, an agency of the California Department of Transportation (Caltrans) with the service operated under contract to the Southern Pacific Transportation Company. It operates over 60 trains a weekday between San Francisco and San Jose, a distance of 47 mi (75 km). Relatively new bilevel coaches are operated in the push-pull mode with diesel-electric locomotives. The line is entirely low platform. Over 23,000 riders per day use the service, which is unique in that it also serves as an intercity rail passenger service between the third and fourth largest California cities. Construction started in 1990 on a 2-mi (3-km) extension of the service to connect to the new light rail system in south San Jose. Extensions at both ends of the present service are under study.

Unique aspects of the service are the use of a Peninsula Pass, which allows commuters to also travel on connecting transit services in Santa Clara, San Mateo, and San Francisco counties, and some free shuttle bus services.

TORONTO AREA

Toronto, Canada, has one of the most efficient and effective rail commuter systems. It is operated by the Canadian National Railways (CN) for the Province of Ontario, and hence is known as GO Transit (for Government of Ontario). Like many North American cities, Toronto grew in area greatly following World War II. Although it always possessed a very effective urban transit system, it depended largely on buses for outer suburban service, with a few scheduled local passenger trains operated at an out-of-pocket loss by the two railways, the CN and CP (Canadian Pacific Rail).



Figure 5-9 Caltrain commuter push-pull train at historic Menlo Park Station. (courtesy of California Department of Transportation)

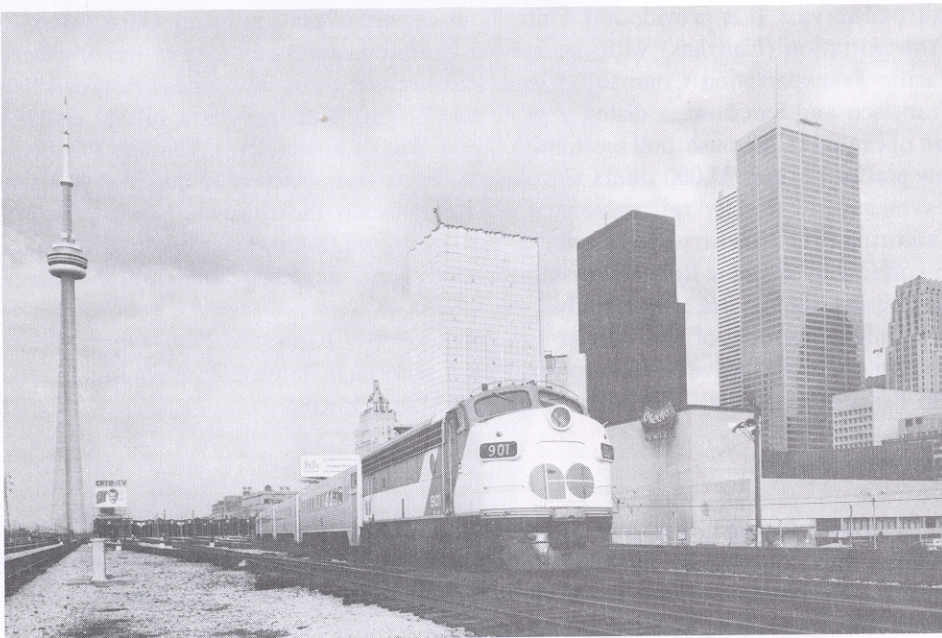


Figure 5-10 GO Transit train. Leaving Toronto Union Station, it is headed by an auxiliary power unit cab, an ex F-97 locomotive (freight/passenger). (courtesy of Toronto Area Transit Operating Authority)

By the early 1960s, it was evident that an outer suburban service on private right-of-way was highly desirable. The high cost of urban freeways caused further pressure to seek an alternative to more freeways. In 1965, GO Transit was authorized, and service was inaugurated in May 1967.

GO Transit provides regular interval service between Whitby 31.3 mi (50.2 km) to the east and Oakville 25.8 mi (41.2 km) to the west, via Toronto's Union Station. A few trains are extended beyond Oakville to Hamilton, 39.3 mi (63.3 km) from Toronto.

basic hourly service is provided, with trains every 20 min during peak hours. Trains have a locomotive at one end with either a driving cab or a former locomotive used as an auxiliary power car with controls at the other end.

Ridership has risen steadily to about 90,000 riders per day in 1989, with additional rolling stock being added periodically. Trains of up to 10 cars are operated, their length being limited by station platforms. To accommodate increasing ridership, a number of double-deck cars were ordered for delivery in 1977-1978, with several additional orders received subsequently. These are true two-floor cars and are not "gallery cars" such as those used in Chicago and San Francisco. Expansion of GO's system to the northwest came in the 1970s, beginning with three round trips per day. Routes to the north and northeast were added during the 1980s. A total of 152 rte.-mi (243 rte.-km) was operated in 1989.

GO Transit is a composite of railroad and transit practices. Fare collection is at stations, allowing a minimum-size train crew. Proof-of-payment was first inaugurated on certain lightly serviced branches to the north. It was successful, as anticipated, so GO changed their entire system to proof-of-payment with tickets vended in stations and roving fare inspectors such as are used on light rail lines in San Diego. Sacramento

to, and San Jose in California and Calgary and Edmonton in Canada. Fares are distance related. Doors are power operated by one conductor, as on rapid transit.

Also included in GO Transit are express buses furnishing direct connections from Oakville to Hamilton on the west and from Whitby to Oshawa on the east. These are not merely feeder buses, but are a continuation of a specific train schedule and stop at stations having park-and-ride lots and enclosed waiting rooms. It is, perhaps, the most effective bus-train service anywhere. These buses are operated by Gray Coach Lines (a subsidiary of Toronto Transit Commission) under contract to GO Transit. The combination provides excellent regional coverage at reasonable cost.

NEW SYSTEMS

Recently, new services have been established in a number of areas. For instance, a moderately extensive and intensive commuter railroad service is provided by MARC (Maryland Rail Commuter of the Maryland Department of Transportation) in the Washington, D.C., area. MARC connects Washington and Baltimore via the electrified Northeast Corridor, as well as the diesel-powered CSX (ex-B&O) line. It also provides

diesel-powered trains to Brunswick, Maryland, and Martinsburg, West Virginia, on former B&O mainline to the west.

In 1989, Tri-Rail inaugurated commuter service on CSX trackage for communities

on Florida's east coast. It connects Miami with West Palm Beach, 67 mi (107 km) to the north. Other new services are planned to operate from Washington, D.C., to points in northern Virginia, from Oceanside to San Diego in California, and from San Juan Capistrano to Los Angeles, also in California.

SUMMARY

The rail mode is versatile. It has provided a 1.5-mi parking lot-to-department store shuttle, the 71-mi Bay Area Rapid Transit system, urban systems covering major metropolitan areas, light rail systems serving busy center-city commercial districts and exclusive suburban residential areas, and far-flung suburban railroad commuter operations.

The versatility of the rail mode can be seen in the examples cited. Track can be single, double, or multiple; it can be at grade, depressed, in subway, or elevated. Signaling can be advanced cab signals with speed control or wayside block signals with or without stop enforcement, or operation can be "on sight" at moderate speeds. Stations can be high or low platform, with or without controlled access. Fare collection can be proof-of-payment (sometimes called the honor system), controlled access (with turnstiles or gates), or conventional fare collection on board. Stations can be elaborate or simple. Track gauge is usually 4 ft 8.5 in standard but can be wide (5 ft 2.5 in as in Pittsburgh or Philadelphia) or narrow (as meter gauge overseas). Power supply is generally 750 V dc, although 600 V dc has been used for some new systems. It all works.

Off-the-shelf applications have been proved and can be implemented with minimal research and development. If evolutionary development of what has been successful is adopted by the planner and engineer, there is a very high probability of successful operation. Construction and operating costs are known and can be projected.

Rail transit has also been proved, and it can do many jobs in the urban and suburban environment. It can use electric power effectively, thus reducing pollution and improving the general quality of life. The opportunities to use rail transit effectively should be kept constantly in mind by the transit planner and engineer because it can be a useful tool.

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FURTHER READING

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Springfield, VA 22161. We have verified the order numbers for many of these citations, and they are found

at the end of the citation. Prices are available through NTIS at the address above.

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PERIODICALS

The following periodicals are suggested for those interested in rail mode. They offer both historical information and current activities.

Electric Traction, The Urban Transit Magazine for Australia. Australian Electric Traction Association, G.P.O. Box 1017, Sydney, NSW, 2001 Australia (monthly).

Headlights. The Electric Railroaders Association Inc., 145 Greenwich Street, New York, N.Y. 10006 (monthly, actually irregular).

Mass Transit. Mass Transit, 210 Crossways Park Drive, Woodbury, NY 11797 (monthly).

Modern Railroads. Modern Railroads, P.O. Box 653, Holmes, PA 19043 (monthly).

Modern Tramway and Light Rail Transit. Ian Allen Ltd., Coombelands House, Addlestone, Weybridge, KT15 1HY,, England (monthly).

Railway Age. Railway Age, Subscription Department, 345 Hudson Street, New York, NY 10014 (semimonthly).

Railway Gazette International. Reed Business Publishing Ltd., Quadrant Subscription Services, Oakfield House, Perrymount Road, Haywards Heath, Sussex RH163DH, England (monthly).

EXERCISES

- 5-1 What are the two essential features of the rail guideway that make it unique and without which it would not work? Why are these features essential
- 5-2 Urban transit does not always employ a standard-gauge rail guideway. Cite examples of the use of nonstandard gauges and the reasons they were used.
- 5-3 Monorails are a popular mode that is being widely installed throughout the world. True or false? Explain your answer.
- 5-4 Light rail is always electrified, using trolley wire with pantographs. True or false? Explain your answer.
- 5-S Cite some examples of high-speed (in excess of 100 ml/h) rail systems. Discuss when the use of high-speed rail is appropriate? Inappropriate?
- 5-6 Some critics of public investment in urban/suburban rail transit strongly contend that such systems have attracted few, if any, new riders to public transit. Is this true? Cite examples.
- 5-7 What is light rail transit?
- 5-8 What is light rail rapid transit?
- 5-9 Since commuter railroads usually operate at a substantial deficit, why should a public agency consider this mode?
- 5-10 The railway, as a mode, is over 200 years old; therefore, it must be obsolete. True or false? Explain your answer.

